GULLY EROSION ON CINDER CONES OF TENERIFE (CANARY ISLANDS, SPAIN)

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1. Introduction

Scoria cones are created by rapid construction stages ranging from days to years and erosion stages that progress at different rates over long temporal intervals. The erosion of cinder cones is a natural process that begins once the eruptive activity ends.

The factors that regulate the erosion of monogenetic volcanoes are: the morphology of the cinder cones, the type and distribution of the material, its age, the topography and the characteristics of the emplacement, the morphoclimatic environment, local runoff depth, etc. The authors recognize two stages, regardless of the factors that intervene in the erosion of the scoria cones (Romero, 1991; Inbar et al., 1994). The first stage occurs once the eruption ends and is associated with the cooling and settling of the different material. In the second stage the erosion of the cinder cones is related to the morphoclimatic environment where the volcanoes are emplaced.

Although there are various processes that erode the volcanoes, creating many different landforms, Hopper and Sheridan (1998) identified gully erosion and alluvial and colluvial processes as the most significant.

The aim of this study is to observe the evolution of gully erosion on cinder cones over time and verify whether or not age is a critical factor in the level of degradation of scoria cones, independent of other factors.

2. Study area

Tenerife, the largest island of the Canarian Archipelago, is characterized by its volcanic complexity. It is formed by the accumulation of different volcanic materials over several million years (Fig. 1). Different types of volcanic edifices can be recognized, among which stand out 297 monogenetic volcanoes. Most of them correspond to cinder cones that have been grouped in five volcanic fields characterized by similar volcanological features (Dóniz, 2004). The basaltic monogenetic volcanoes, characterized by effusive and explosive strombolian activity.

Currently Tenerife has no permanent waterways. Drainage on the island takes place via gullies with broad heads and deep, narrow drainage channels that are only active intermittently. This situation is caused by atmospheric instability in the form of storms from the NW and the SW. Tenerife receives around 300 mm of precipitation per year (Marzol, 1988), distributed throughout the fall and spring months. Torrential erosion is caused by violent downpours that are highly concentrated in time and extremely intense. This kind of precipitation can produce more than 100 mm of water in 24 hours; 50 mm/day or more can lead to geomorphological consequences (Marzol, 1988).

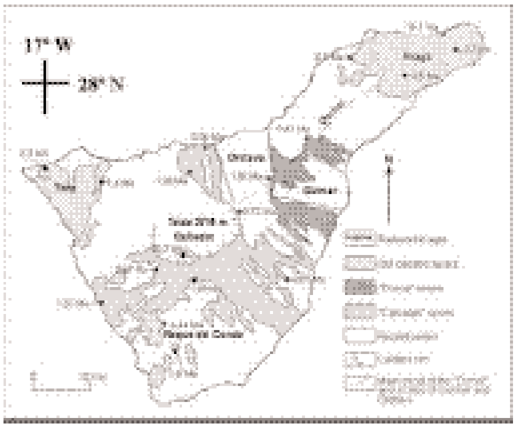

Fig. 1. Geological map of Tenerife (Ancochea et al., 1990).

3. Methodology

The methodology employed is based on a geomorphological study of monogenetic volcanoes (1:10,000 topographic and 1:25,000 geological cartography, 1:18,000 aerial photography and field work), as well as the morphometric analysis of hydrographic networks developed by Strahler (1988) and the morphometric relationships of cinder cones proposed by Wood (1980) and Dohrenwend et al., (1986). Only volcanoes with absolute dates (Fig. 2) and gullies originating within the craters and on the flanks of the volcanoes that are not associated with run-off produced upstream from the emplacement of the volcanic edifice were studied.

4. Results

The 43 cinder or scoria cones dated in Tenerife correspond to 14.48% of the whole island (Fig. 2). Thirty cinder cones (69.77%) were created in the last 10Ka (Holocene) and the other 13 (30.23%) are Pleistocene.

Because the processes leading to morphological transformation that have had the greatest impact on the volcanoes are associated with torrential rains (Dóniz, 2001 and 2004) the relationships between the 43 dated volcanoes and their gullies.

Only 39.54% of these volcanoes have gullies. More than 84.6% of the Pleistocene cones have gullies, compared to only 20% of the Holocene cones. This means that Holocene cones without gullies constitute 80%, while the Pleistocene

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cones barely reach 15.38%. Therefore, it appears that the older a volcano is the more it will have been incised by torrential rain.

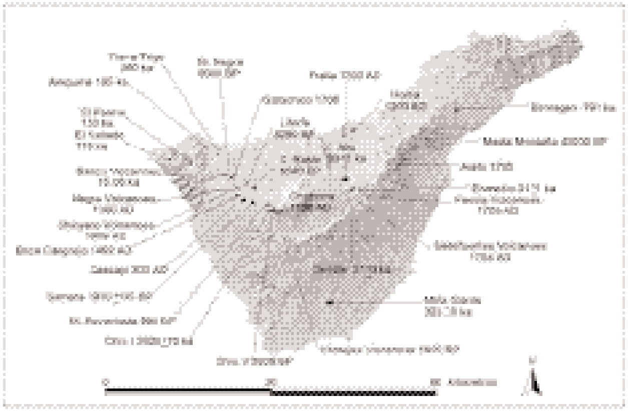

Fig. 2. Ages of the cinder cones of Tenerife (based in Carracedo - coord.- 2006).

The drainage network of these 17 volcanoes is made up of 70 channels with an average of 4.1 gullies per cone. There is no difference between the total number of thalwegs carved on the flanks and craters of the cones. The hydromorphological importance of both groups of gullies is not equal since 94.1% of the erosion volcanoes have channels in their craters forming centripetal catchment basins that are at the most 2nd order. The dorsal channels are not always distributed radially and they never form a hierarchical network since they never surpass 1st order. The majority of the gullies on the flanks are located on the most pronounced gradients, producing parallel asymmetric networks. The asymmetry of the morphology of the cones caused by the gullies is accentuated in steep areas and water divides and attenuated in areas with little or no gradient, or in areas characterized by a lack of running water due to recent volcanic activity (Romero et al., 2006).

5. Discussion and conclusions

Some authors (Wood, 1980; Dohrenwend et al., 1986) claim that as the age of the volcano increases so to does its dismantling and therefore it tends to diminish in height (H_{co}), volume, slope and crater depth (D_{cr}), while the diameter of the crater (W_{cr}) and cone (W_{co}) increase. The H_{co}/W_{co} and D_{cr}/W_{cr} indexes are greater when the cinder cones are more recent; The W_{cr}/W_{co} index evolves inversely (Wood, 1980).

The morphometric study of these volcanoes by age intervals reveals that in Tenerife the H_{co}/W_{co} and D_{cr}/W_{cr} correlations do not evolve according to Wood's postulates, but instead they evolve inversely (Table 1).

Table 1. Indexes for morphometric parameters.

Group Age	Cinder cones	%	H_{co}/W_{co}	W_{cr}/W_{co}	D_{cr}/W_{cr}
Holocene	30	69.78	0.18	0.62	0.24
Pleistocene	13	30.22	0.20	0.51	0.31
Total	43	100	0.19	0.57	0.27

Although the Pleistocene volcanoes have been most incised (between 5 and 12 channels) the degradation of the cinder cones analyzed in Tenerife does not appear to depend on the amount of time that has passed since their creation. In this sense, all of the Pleistocene volcanoes that have a large number of gullies (Tierra Trigo, Birmagen. M. Gorda, Alto, Enmedio and Media Montaña volcanoes) are always emplaced on water divides between large cathment basins, ranging from 4th and 5th orders. However, it must be kept in mind that there are Pleistocene volcanoes that are older and that have been incised less by erosional gullies (between 1 and 4 gullies) emplaced within lower-hierarchy basins (Vallado, Aregume and Palmar cinder cones). In addition, there are Holocene scoria cones (Chío, Horca, Cascajo) that have the same number of gullies as Pleistocene volcanoes (Liferfe, Banco or Cueva Ratón). All of this illustrates the fundamental role that the emplacement of a volcano plays in its torrential remodelling.

Therefore, although the age of a volcano is an essential factor in the degree of torrential erosion it has gone through, there are other types of factors that intervene as well. The rate and evolution of these volcanoes depends on a combination of these factors.

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